

Title

Design, manufacture and construct procurement model for volumetric offsite manufacturing in the UK housing sector

Abstract

Purpose

The purpose was to gain insight into procurement routes and forms of contract used for volumetric offsite manufacturing in the housing sector of the UK West Midlands. Seminal literature and government reports have established the potential of offsite technologies to improve the supply of quality housing in the UK. However, the lack of a structured procurement route, common to manufacturing approaches in construction, has significantly contributed to delays in large scale adoption.

Design/methodology/approach

To achieve the research intention, an exploratory study was undertaken. A literature review of seminal literature and government papers was conducted to establish and benchmark current trends in context. Data was collected using focus groups and interview with a housing association and housing volumetric offsite manufacturers. Grounded theory was employed to analyse data and inductively generate themes leading to an original procurement model. The issues identified in the delivery of volumetric housing were categorised into three themes.

Findings

The findings suggest a limited familiarity with offsite manufacturing by housing providers. Albeit, a willingness to adopt these technologies to deliver housing were demonstrated by trial attempts. However, due to limited knowledge the approach to procurement is by adapting existing procurement models which are not ideal and obstruct the potential benefits of using offsite technologies primarily due to the significant difference in processes. Also, geographical location influenced procurement decisions when comparing cost with conventional procurement and the dearth of specific government incentives to deliver housing using offsite technologies. This study proposes a procurement model for volumetric offsite manufacturing.

Practical implications

The results have implications for decisions about procurement routes and contractual terms employed by housing providers delivering volumetric offsite manufactured housing at scale. Although this study focused on the West Midlands region, most of the issues identified were not geographically unique.

Originality/value

This study contributes to the existing body of knowledge on potential barriers to the adoption of offsite manufacturing in the housing sector of the UK. The findings will be of value to stakeholders involved in delivering housing and offers a useful contextual basis for future research.

Keywords

forms of contract, housing, procurement, volumetric offsite manufacturing.

Introduction

Over ten years ago, Nadim and Goulding (2010) reported that the majority of 36 large construction organisations who responded to their survey believed offsite production to be the future of the UK construction industry. Taylor (2010) forecast the value for the UK offsite construction sector in 2013 to be £4.9 bn. The Construction 2025 Report (HM Government, 2013) advocates a wider offsite manufacturing strategy. Rahman (2014) argued that modern methods of construction, including modular building and offsite manufacturing, have the potential to meet increasing housing demand. The Farmer Review's (Farmer, 2016) recommendations included that the housing sector should be used as a scalable pilot programme using industry, clients and government collaboration to change commissioning trends from traditional to pre-manufactured approaches and the Government should act to provide stimulus to innovation in the housing sector by promoting the use of pre-manufactured solutions through policy measures. There is therefore shared government and industry aspiration for implementation of an off-site manufacturing (OSM) strategy, particularly in the housing sector. However, scaled adoption remains unattained amidst increasing pressure from the housing crisis.

Research justification

Goulding and Rahimian (2020, p.5) explain that a barrier to OSM adoption is lack of comprehension of the requirements to fulfil an OSM business strategy with issues raised including *"procurement options and legal compliance"*. Hammad et al. (2020) argue that established procurement models are arrangements made for site-based work, the nature of associated risks are therefore different from having those activities that take place in a controlled manufacturing environment. They also identify that builders unfamiliar with OSM commonly lack confidence in procurement routes and argue that an appropriate procurement strategy would probably contribute to an increased adoption of OSM. Goulding and Rahimian (2020) advocate the need for radical change to promote OSM sector resilience requiring fresh ideas and new business models.

Recent trending topics and themes in offsite construction research identified organizational management, supply chain and context as under-researched themes (Liu et al., 2019). Agapiou (2020) categorised legal and contractual issues affecting the use of OSM within UK housebuilding into four central domains: process, policy, enforcement and culture. This research initially focused on process which includes interface and accountability and regulation of the contractual relationship in the context of procurement and forms of contract.

Terminology

Sutrisna and Goulding (2019, p. 269) opine that *“The panelised structures and modular are typically considered volumetric offsite construction”*. Hammad et al. (2020, p.191) concur with this definition *“panelised structures and modular are typically considered as volumetric OSM, which includes manufacturing of and site installation of pods and modules.”* The authors have adopted these definitions of Volumetric Offsite Manufacturing (VOSM).

Context

The section examines procurement, offsite manufacturing and housing policy then off-site manufacturing procurement and forms of contract.

Procurement

El Asmar et al. (2013) define a project delivery system as determining the relationship between the different project stakeholders and their timing of engagement to provide a built facility. Mesa et al. (2016) identify three primary construction project delivery systems: design-bid-build (DBB), construction management at risk (CMR) and design-build (DB). Small (2020) recognises the primary procurement methods as traditional, design and build, construction management and integrated project delivery.

In DBB, also known as traditional procurement, the client has separate contracts with the designer and contractor. The designer provides design services, based on the client's requirements, delivering plans and specifications for the construction of the project. A contractor is then selected by the client to construct the project (Hale et al., 2009). DBB is the dominant procurement in the UK and is primarily preferred by one-off clients who rarely engage in construction. Rahmani et al. (2017), in their review of the historical development of construction procurement methods, identify that traditional procurement may fail if a contractor is appointed before the design is complete due to the prospect of post-contract changes causing delay to the works and an increase in costs. Akintan and Morledge (2013) aspire to improve collaboration between the main contractor and subcontractors within traditional construction procurement projects.

For design and build (DB), the client only has a contract with a single design and build contractor who delivers both the design and construction. Hale et al. (2009) research on similar projects concluded that DB performance regarding time and cost was better than DBB. The NBS (2018) report records that traditional procurement remains the most common method with 46% of professionals rating it as their most used method followed by design and build with 41% usage.

Construction management provides the client with separate contracts with the designer and the constructor. Mohsini et al. (1995) found that construction

management solves some of the problems of traditional building process but creates others, particularly when there is a major difference between the levels of sophistication of the participants.

El Asmar et al. (2013) comparison of IPD with DBB, CMR and DB concluded that IPD achieves statistically significant performance providing higher quality facilities faster and at no significant cost premium. Mesa et al. (2016) explain that integrated project delivery (IPD) emerged as a new delivery system with the potential to improve performance through increased supply chain integration. The client, designer and contractor sign one multiparty contract.

Offsite manufacturing and housing policy

The London Assembly (2017, p.9) August 2017 Planning Committee report mandates the Mayor to *“Set up a London-specific OSM led procurement framework. The key objective would be the attraction of a sufficient number of developers and contractors capable of delivering housing using a range of OSM led solutions and which are suitable for the variety of sites and typologies and all the specific challenges that exist in London.”*

The House of Lords (2018) Science and Technology Select Committee Report recommends that:

- The construction sector needs to build trust and partnerships so that companies can work together to improve the uptake of off-site manufacture.
- Designers, contractors and suppliers must all have early involvement in a project for off-site manufacture to be successful.
- The role of Government and the wider public sector is pivotal in a move to greater use of off-site manufacture.

The report also notes the Government’s ‘presumption in favour’ of off-site manufacture on all publicly funded construction projects from 2019 (HM Treasury, 2017).

In December 2018, the Housing, Communities and Local Government Committee launched an inquiry into modern methods of construction (MMC), including off-site manufacturing, and their potential role in boosting house supply (Commons Select Committee, 2018). The inquiry references the Government’s Industrial Strategy which promotes MMC as having the potential to reform the residential construction sector to meet its target of 300,000 new homes each year and 1 million between 2017 and 2020. The Chartered Institute of Housing (2019, p.4) submission in response to the inquiry advocates *“Centralising the building assembly process, avoiding a large proportion of the on-site work where standards are more difficult to enforce.”*

Off-Site Manufacturing Procurement and Forms of Contract

The results of 30 interviews with housing industry construction professionals, particularly members of Buildoffsite organisations, indicated that a regulatory key constraint was *“No legal framework available to support OSM”* (Elnaas et al., 2014, p.54). Mosley and Bubshait (2017) catalogue the rationale for selecting different procurement schemes including taking advantage of innovation. Design for manufacture and assembly (DfMA) has been successfully deployed including for high-rise residential construction (Banks et al., 2018). However, Arashpour et al. (2016) advocate a holistic approach where risk management for on-site and off-site project activities are integrated. Dowsett et al. (2019) recommend the integration of housebuilders and suppliers of modern methods of construction (MMCs) to foster the implementation of more sophisticated modular and volumetric off-site solutions.

Historically, housing in the UK has been delivered predominantly as site-based construction with evolving supporting standard contracts (Lupton et al., 2019). Lau et al. (2019) recognise that the developing complexity of construction schemes has considerable influence on procurement arrangements and forms of construction contracts. However, in their study of the challenges to the adoption of the new engineering contract in Hong Kong, the researchers discovered that resistance to change was ranked first overall and first also by clients.

Finnie (2018) proposes a two-stage early contractor involvement model: with a pre-construction contract followed by a standard-form construction contract to enhance OSM procurement. He asserts that the model contributes to the development of a standard form for pre-construction contracts. The choice of a standard-form of contract is significant (Charlson, 2019).

Agapiou (2020) advises that existing standard forms of contract for example, JCT and FIDIC may not be appropriate for OSM projects. Instead, he suggests a pre-construction phase contract between contractor and OSM, such as JCT's pre-contract services agreement, which could ameliorate design interface issues which may occur between manufacture and installation of the modules on site. The NBS report (2018) records the most frequently used contracts as JCT (62%); NEC (14%); bespoke (5%) and FIDIC (4%). Small (2020, p.392) argues that *“Implementation of alternative forms of project delivery will also require a ‘sponsor’ or ‘change-agent’ to drive/advise potential owners to employ alternative contract forms.”* He identifies legal frameworks as an inhibitor of the implementation of OSM.

The Construction Leadership Council (2017) position paper aims to develop a compelling proposition for housing clients to increase demand for smart construction and provide volume surety to enable greater investment in industrialisation. This paper calls for (p.3) *“revised procurement guidance and model forms of contract, with appropriate measures to manage risk investment and reward collaboratively and transparently.”*

Research methodology

The literature review provides evidence that the proposed research is both needed and significant (Fink, 2014). This research is an exploratory study. A relativistic (where reality entirely depends on human interpretation and knowledge) ontological position (Brawn and Clarke, 2013) and constructionist philosophical paradigm (Crotty, 1998) were chosen. The researchers adopted grounded theory methodology *“which involves a systematic process of gathering and analysing a finite set of data to evolve a theory based upon the data”* (Hunter and Kelly, 2008, p.86).

The purpose was to understand procurement routes and forms of contract used for volumetric offsite manufacturing in the housing sector of the West Midlands. A qualitative approach comprising open-ended questions followed by thematic interpretation (Creswell, 2014) was followed. The emphasis was on insight and interpretation (Fawcett and Pockett, 2015) to inductively generate theory (Bryman, 2016). Data collection was by focus groups and interview (Silverman, 2011). The organisations and individuals were anonymous but, their responses were recorded and then transcribed to ensure accuracy. Theoretical sampling (Schwandt, 2001) was selected allowing relevant cases to be chosen. Fawcett and Pockett (2015, p. 56) argue that *“...as qualitative researching does not look to generate validity, reliability and generalizability, statistical or random sampling does not feature.”*

In accordance with grounded theory, data collection involved multiple phases, refinement and interrelationship of categories (Creswell, 2014). In phase one, data was collected from multiple West Midlands sources including focus groups and a one on one interview with an expert. Initially, two focus groups were conducted with participants with from key stakeholders: a housing association (HA) and an offsite manufacturer.

The first focus group included representatives from the HA which is one of the largest social housing providers in the West Midlands with almost 12,000 homes for rent. The second focus group included participants from a volumetric offsite manufacturer (VOSM) of residential housing solutions constructed using high-integrity modules engineered and built in their own factory facilities. Each focus group included representatives from different disciplines and organisational backgrounds including a Development Manager (with over 40 years' experience in social housing), an Operations Director (who had submitted evidence to the House of Lords *Off-site manufacture for construction* inquiry), a Sales Director (who has 11 years' off-site manufacturing experience) and an Employer's Agent (qualified as a Chartered Quantity Surveyor). The focus group discussions were initiated with open-ended questions and centred on procurement routes and forms of contract used on delivered projects. The duration of the discussions was between one and two hours; they were recorded for transcription and analysis. The focus groups were followed by a one on one expert interview with an Operations Manager (who has over 15 years'

experience working for off-site manufacturers) for a different manufacturer (OSM) providing both traditional and closed panel timber-frame housing solutions.

In the second phase, the collected transcribed data was coded using the principles of thematic analysis. Themes are described as recurrent and distinctive elements of participants' accounts which characterise their perception and are relevant to the research question. As recommended by King (2008), NVivo software was used to analyse the qualitative to facilitate the nonlinear and iterative process of grounded theory. First, initial coding began with examining the data set to identify patterns, label categories and commence comparison between codes. Subsequently, gaps existing in the data set were highlighted and theoretical sampling was then employed to direct the collection of further data (Mills et. al., 2014). Theoretical sampling generated data focused on gaps and advanced the iterative process until theoretical saturation was reached (Chun Tie et al., 2019). Then focused coding built on initial coding to evolve data into themes. Theoretical coding established the relationship between themes giving rise to theory that is grounded in the data. This process is detailed in Figure 1 – *“Grounded Theory Research Methodology”*.

A third phase of the investigation evaluated the findings. An event focused on the latest developments, innovations and investments being made in the volumetric modular offsite sector, outlining the reasons why the offsite supply chain is appealing to ground-breaking clients, was identified. At this event experts, not restricted to the geographical region of this study, were interviewed. Experts were selected on the basis of their experience in procurement of offsite manufacturing. To elicit participants' views, open ended questions were asked in one on one sessions. Probes were used to clarify views and opinions. The data collected was used as a basis to evaluate credibility and guide revisions to the DMC model. Charmaz (2006) argues that a grounded theory study can be evaluated against the following criteria: credibility, originality, resonance and usefulness.

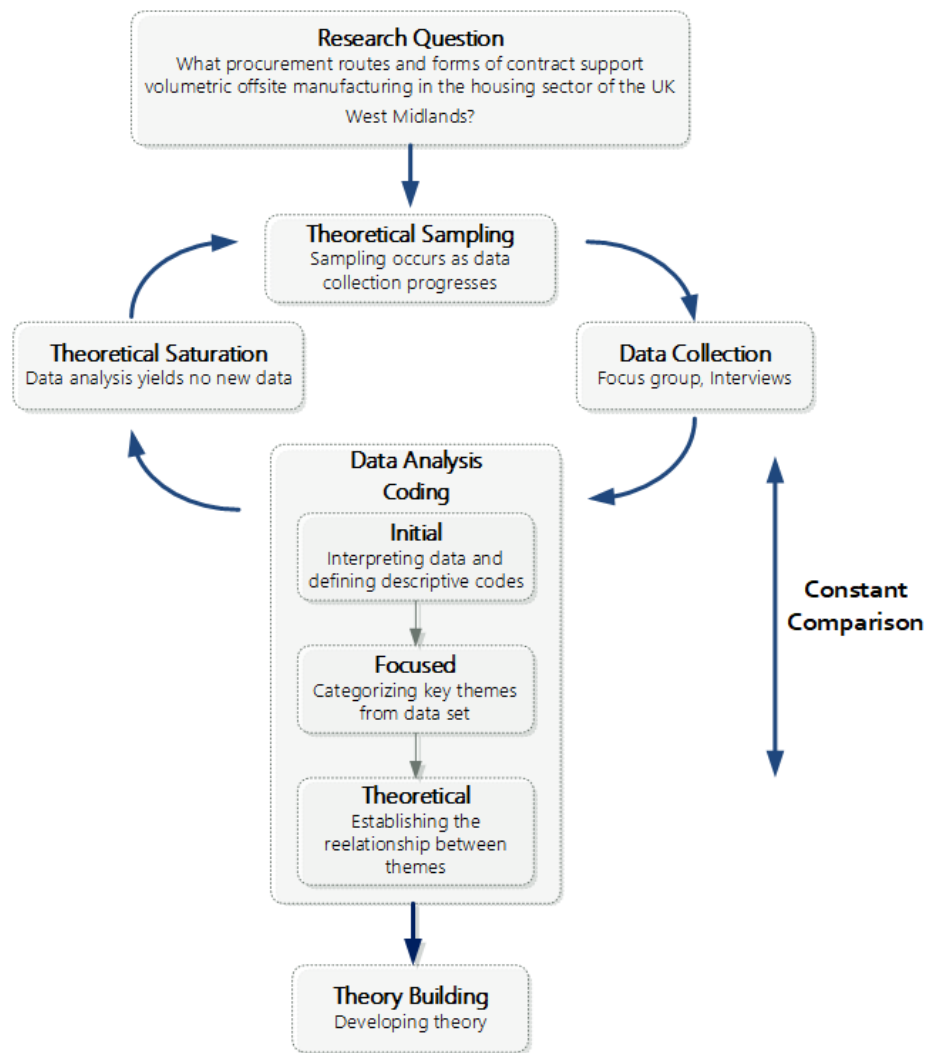


Figure 1: Grounded Theory Research Methodology

Results

First, the procurement and contract structure of the HA's first volumetric offsite manufactured project is detailed. Then, results of the focus groups and interview are then reported under the procurement, contracts and manufacturing categories.

HA VOSM project- procurement and contracts

The HA focus group initially discussed their first OSM housing project which was encouraged and incentivised by the then Homes and Communities Agency. It was part of a wider scheme of traditionally constructed properties. The project was initially intended to be fully delivered using offsite manufacturing. However, a strategy of four VOSM modular units together with 27 traditionally constructed dwellings was developed primarily due to the lack of framework/understanding of offsite construction. An architect on the HA's framework, an employer's agent and principal designer were appointed. The architect designed the initial site layout and

unit types primarily for the planning application. The initial VOSM manufacturer was identified on the Central Housing Investment Consortium (CHIC) Buildsmart framework. Unfortunately, this VOSM manufacturer then became insolvent. Subsequently, a local company offered to undertake the project at the same price as the original because they aspired to enter the housing market from their experience in schools and educational buildings.

Other contractors tendering intended to follow their normal model of undertaking all the site work including the ground works themselves. However, for this project, the groundworks were delivered by the traditionally constructed properties contractor. The contract was *JCT design and build 2016* for 27 traditional houses and 4 infrastructures and substructures. The OSM manufacturer was also contracted on a *JCT design and build 2016* for the supply and fixing of the four VOSM units. The contract structure of the HA's first volumetric offsite manufactured project is set out in Figure 2 – “Housing Association Contractual Arrangements”.

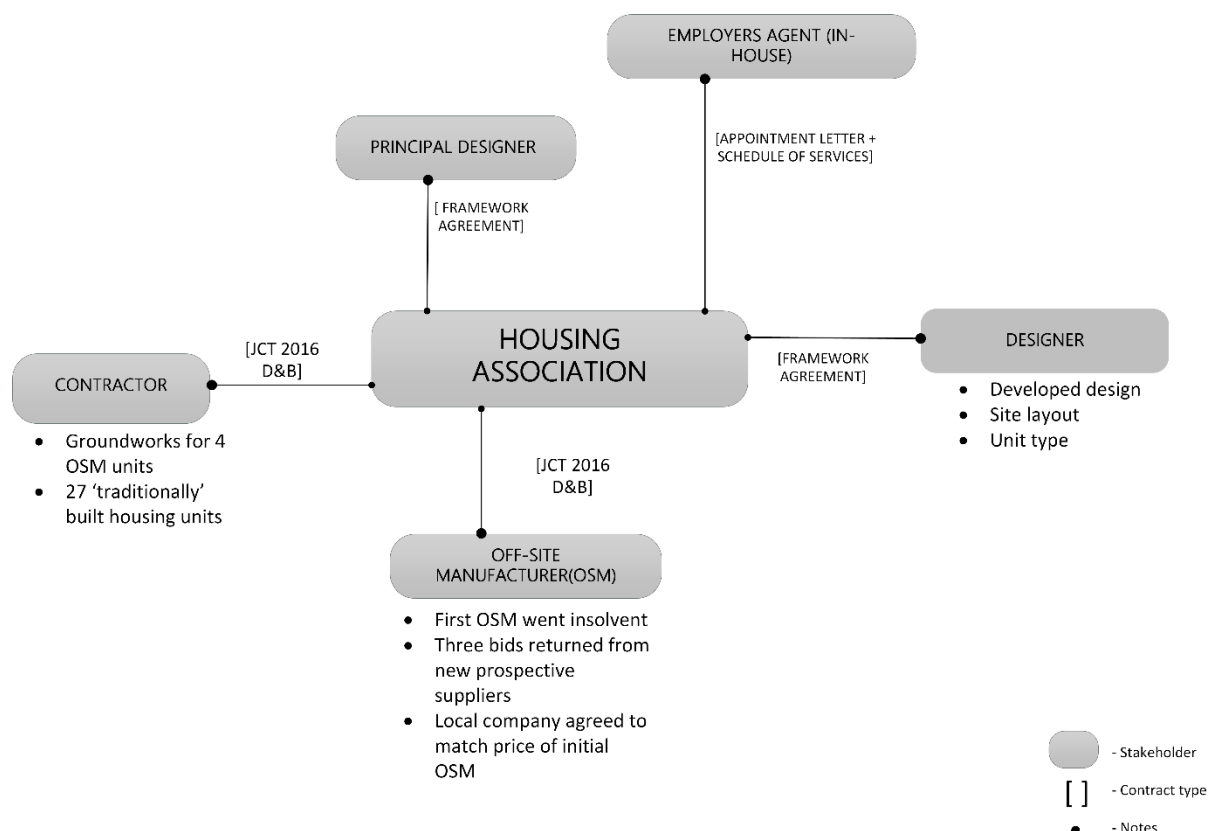


Figure 2: Housing Association Contractual Arrangements

However, the VOSM manufacturer normally undertakes the groundworks too. The HA acted as developer to ensure warranty and mortgage provision. The HA in-house team completed the project by turfing, paving and fencing. The project was considered to be a success primarily because all parties were invested in its favourable outcome.

HA and VOSM focus groups and OSM interview

The results of the HA and VOSM focus groups and OSM interview are reported under the headings procurement, contracts and manufacturing. The NVivo themes are shown in Figure 3 – “Themes generated using NVivo”.

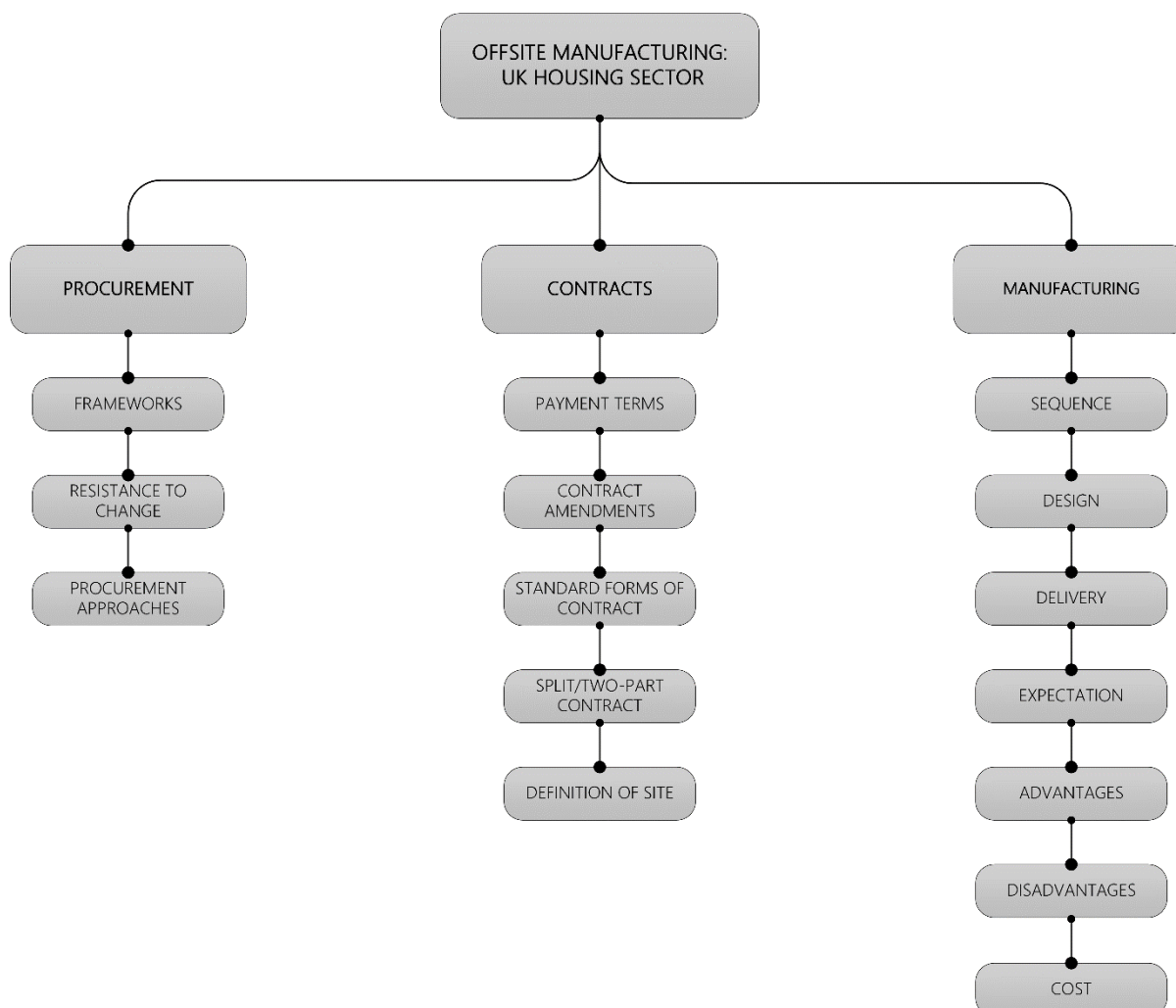


Figure 3: Themes generated using NVivo

Procurement

This section discusses frameworks, resistance to change and procurement approaches.

Regarding housing delivery, the OSM interviewee stated ‘*procurement process and tender process is quite lengthy. That poses challenges in itself because of the lead times involved.*’ However, joint ventures and frameworks, which list OSM suppliers, were found to decrease turnaround time and boost confidence in suppliers as they would have satisfied certain criteria (e.g. BOPAS accreditation) to be listed. The OSM interviewee explained ‘*we’ve gained some projects through the LHC framework.*’ Both OSM and HA focus groups offered suggestions for joint ventures/partnerships as mechanisms to foster OSM’s growth in housing.

Resistance to delivering OSM housing units was explained by the OSM interviewee *'We've found a lot of housing associations and councils are quite enthusiastic about off-site manufacture and utilising it, but the developers and a lot of the construction companies that are so used to traditional build, or what they've been doing for years, they've been a bit more resistant to the change.'* Typically, housing sector clients have preferred suppliers which presents challenges for OSM procurement. The OSM interviewee said *'I think also where we get problems as well, we'll have a client that wants our system ... they'll have a preferred developer to do their sites, and then we're being foisted upon the developer who may not want to use us'.*

The VOSM focus group contrasted established procurement with OSM acquisition *'It's not like a traditional construction where there are thousands, literally thousands of main contractors and big builders, who all want that business. Here, we've got a handful of companies, a handful of people who've made the capital expenditure, made that investment.'* Volumetric OSM was advocated as the solution to the UK housing deficit as an OSM production line relies on and can deliver volume manufacturing.

This study identified a variety of methods by which offsite manufacturing is procured in the housing sector. However, design and build was found to be the most commonly adopted procurement approach. For the future, the OSM interviewee commented *'I think you're seeing a move towards more modular systems .. more is being looked to be developed off site and then delivered to site as a complete package.'* The VOSM focus group reported an initially sceptical Development Director, after their project stating, *'Yes, it was good. I see it's the future.'*

Contracts

This section addresses payment terms, contract amendments and standard forms of contract, a split/two-part contract and the definition of site.

A significant contractual issue identified was payment terms. In the HA focus group, regarding OSM procurement it was argued that *'I think the biggest disadvantage is the payment terms.... You'll have paid for probably 80 per cent of your contract value before anything's even arrived onsite.'* It was explained that HA governance and funding made it unusual for 80% of the project cost being paid before the units were on site. Similarly, in the VOSM focus group, a participant complained *'number of days, but not schedules of payments. You just put that as appendices, but it doesn't really fit in, so there's no classification of a deposit.'* On another OSM project the client had identified similar difficulties *'We use the listed items clause in the contract, and you have to have vesting certificates'.*

The VOSM focus group reported their frustration with clients endeavouring to amend standard forms of contract *'..I mean, they took out 70 clauses that were just nothing to do with what we were doing, but they didn't add any in that did seem what we were doing'.* However, the OSM interviewee reported that *'we've done a couple of*

contracts under the JCT contract.’ The VOSM focus group concurred ‘They’ve all been JCT... design and build’ but advocated for ‘JCT Modular’. The HA focus group reported ‘There is quite a lot of talk out there in the industry ... that they’re drawing up a bespoke contract for OSM. I’ve not seen any version of it, but I can understand why, because it is totally different to trad construction.’

The VOSM focus group complained that, due to the lack of a standard form of contract appropriate for volumetric housing delivery, they undertake activities which add value to the client when not under contract for example, obtaining planning permission. They have had several instances where prospective clients decided against OSM delivery in favour of an alternative and as a consequence of a lack of contract protection, no payment was received for these services. They argued for a ‘split/two-part’ standard form of contract *‘There’s a contract in place that would follow through to the end, but there is a segmentation there that allows you to be paid up to a point, and that stuff that’s beneficial to them.... If that was in the contract, where we could segment it. There would be a, I wouldn’t say a penalty, but a fair line drawn that if you don’t carry on, then you owe this, which is the work that has been done in the past’*

The VOSM focus group argued regarding their factory that *‘...we need this to be seen as a site, so when the materials arrive here, they’re classed the same as if they arrived on a site we put up on their site. At the moment, they’re not, so they would only vest to a certain amount with the materials....so that’s quite a big one’*.

Manufacturing

This section discusses sequence, design, delivery, expectation, advantages, disadvantages and cost.

The stages of OSM may appear similar to traditional procurement e.g. design, then invitation to tender for the construction but the nature, sequence and duration seem to be unfamiliar to housing clients. The OSM interviewee explained *‘Our biggest problem is getting the client to understand our system and buying into it and agreeing details and everything up front’*. He remarked that *‘Where projects have failed, I think the biggest problem has been where clients or developers aren’t used to offsite manufacture’* and argued that *‘what needs to be done to make sure that the projects run smoothly, is the engagement upfront’*.

It was argued that volumetric OSM requires the design to be finalised in advance of manufacture. The approach for volumetric OSM is Design for Manufacture and Assembly (DfMA) with the design based on a supplier’s system. Therefore, the designer must be knowledgeable about the system and design finalized before manufacture begins. The OSM interviewee explained *‘When they’re building traditionally, drawings and details can be developed a lot later in the process. Whereas, when you’re taking on board a system that’s involved in off-site manufacture, getting those details and drawings finalised, drawn up and agreed*

needs to be done a lot earlier in the process.' Additionally, OSM designers are required to possess a BOPAS (Buildoffsite Property Assurance Scheme - which requires design, manufacture and on-site installation to be verified) accreditation. Therefore, in-house OSM designers are dominant *'There are very few external designers who are actively involved in this knowledge.'*

The OSM interviewee explained that they are able to provide packaged solutions (single point responsibility); *'We can actually offer you a turnkey solution from design all the way through to completion on site'* by subcontracting the site groundworks. He continued *'We're trying to put together a package where our construction services will develop the site.'* Alternatively, installation could be undertaken by the client's team. The OSM interviewee explained *'We have approved contractors that we've used and have been through our training If a client wants to use their own team, then again, we will talk them through our system.'* The HA focus group shared their experience of turnkey provision *'a lot of them are trying to set themselves up in the market, and their selling point, they think, is being able to deliver the whole lot on-site'*. The study found most of the OSM suppliers were on frameworks as such arrangements supported their processes and encouraged buy in from clients. Indeed the HA focus group recommended procurement *'Via a framework, because we thought that was the best route, feedback on their expertise.'*

The HA focus group reflected *'I think, because we thought this is the new world, it'll be quicker, cheaper. It's already quicker, but it then gets tied up with other processes, and slowed down, so it wasn't even quicker, and it was more expensive. Why do anymore?'* Nevertheless, there was recognition of OSM in the housing sector as *'Trying to bring in experience from other industries into the construction industry to try processes and procedures'*.

The advantages of a manufacturing approach for housing were established by the HA focus group as *'The benefit of offsite, if you can get a same standard product and roll it through the factory, that's going to develop the efficiencies'* and *'It's about keeping the big production line going. Like any sort of process. Car manufacturer, etc.'* The HA focus group identified the health and safety and environmental benefits identified as *'It is better from a health and safety point of view, because it's all at low level'* and *'They know all their wastage, and they're bringing the stuff back, and they're recycling it.'*

The disadvantages recognised included *'You're not going to deliver your units to site until all the way down here. Whereas in that time its taken to get all that in place, you could be building a lot of traditional construction onsite'* and *'Everybody here thought the units would be delivered ... and people would move in the next day. It doesn't work like that, because you've got to get your services in. In this instance, we had to get the drainage in. We couldn't do any of those groundworks before.'*

The study observed cost as a significant factor for clients on deciding whether to employ OSM. Location was noted to influence tender price for example, the HA focus group found OSM significantly more expensive than traditional tender prices for the same project; *'It was just too expensive, we tried.... It's about £300-a-square-metre more expensive'*.

Discussion

The advantages of OSM joint ventures and frameworks in providing pre-approved suppliers and shortened procurement processes were recognised. Developers and construction companies as key stakeholders in the housing sector were identified as being resistant to change. Lau et al. (2019) recognized clients' reluctance to change. The limited number of OSM suppliers was highlighted. Design and build was found to be the default procurement method which buttresses the resistance to change and partly explains the approach to adopting OSM. The aspiration of OSM as single point of responsibility is consistent with design and build procurement except for the difference in process. However, the data suggested a willingness to adopt OSM technologies but stakeholder education was lacking.

An important concern for both the HA and VOSM was that the payment terms of standard forms of contract do not match the cost profile of OSM procurement. A greater proportion of the cost is incurred in the factory before units are delivered to site. Standard forms of contract do not accommodate payment of a deposit and instead payment schedules are added as appendices or advance payments are made protected by vesting certificates. Charlson (2019) highlights the consequences of selecting an inappropriate standard form of construction contract.

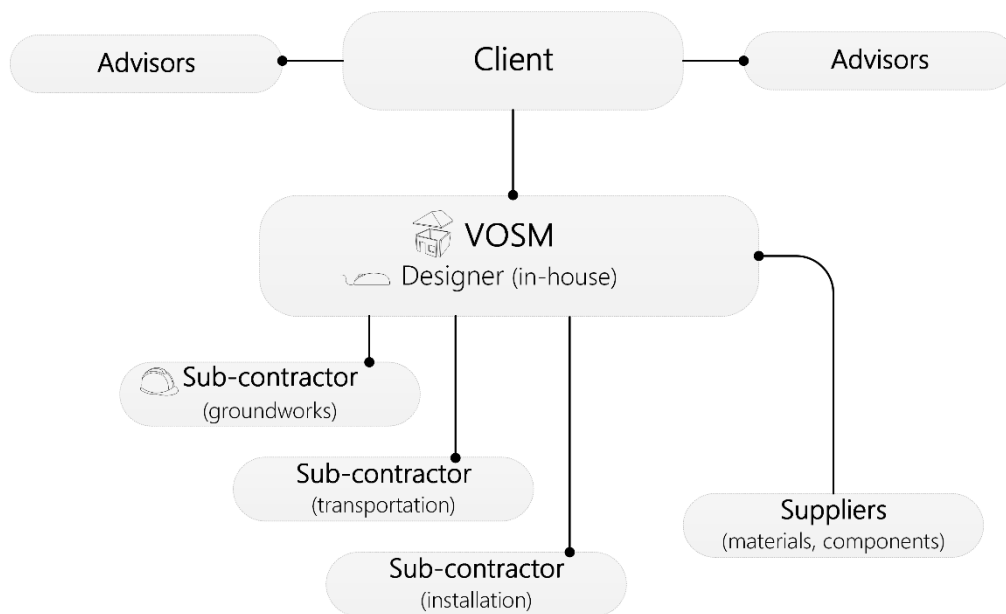
The VOSM focus group stated their difficulties with clients' inadequate amendments to standard forms of contract which resulted in incurring increased risk exposure and financial losses. For example, to attain client buy-in, planning permission would be obtained only for their services not to be remunerated when clients decided against an OSM approach. In view of a solution to balance such risk exposures, they proposed a new fairer 'split/two-part' contract for volumetric OSM. Finnie (2018) argues for a two-stage early contractor involvement model but recognises that a standard form for pre-construction contracts is required. However, regular use of JCT contracts was reported and development of a bespoke OSM standard form of contract is advocated. For OSM projects, the definition of "site" should benefit from revision to reflect that a substantial percentage of the work is completed and cost incurred in the factory in advance of delivery to site.

The VOSM focus group championed OSM knowledge and understanding and early engagement by clients and developers. Rahmani et al. (2017) identified that traditional procurement may fail if a contractor is appointed before the design is complete. Volumetric OSM depends on a completed design before manufacture. This finding accords with Rahman's (2014, p. 72) analysis of the barriers to

implementing modern methods of construction in the UK which ranked *'inflexibility for late design changes'* and *'early design freeze'* as second and fourth concerns respectively. The designer must understand the manufacturer's system and so design is usually undertaken in-house with few outside designers. Turkey solutions have emerged incorporating design, manufacture and construction. A choice of using a client's own team for installation can be available. However, the VOSM noted the risk of engaging external teams for example, designers and installation team to the quality of the finished product before scale adoption is achieved in the sector.

The benefits and challenges of OSM were diagnosed including a production line approach with health and safety and environmental advantages. However, clients can have unrealistic expectations about the speed of completion. The research noted that cost is an important issue for clients choosing OSM, they sometimes discovered it to be significantly more expensive than established construction methods.

Sutrisna and Goulding (2019) recognise the lifecycle of the offsite construction projects as design, offsite (manufacturing), handling and transporting, site works and installation followed by occupancy. By incorporating the results of this research, the offsite construction lifecycle has been developed into a design, manufacture and construct procurement model for volumetric offsite manufacturing in the UK housing sector: Figure 4 – *"Design, Manufacture and Construct Procurement Model"*. The model represents integration as advocated by Dowsett et al. (2019); is a response to innovation as anticipated by Mosley and Bubshait (2017) and a development from DfMA (Banks et al., 2018).



SEQUENCE

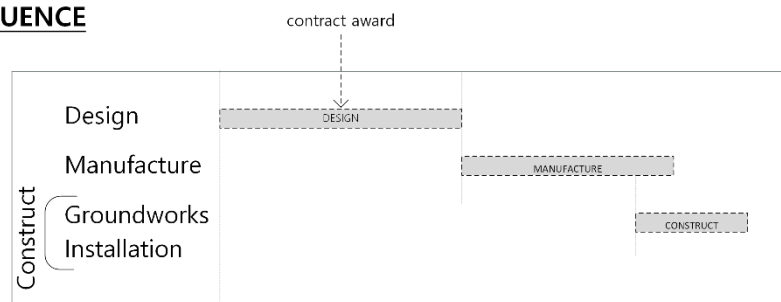


Figure 4: Design, Manufacture and Construct Procurement Model

Hubbard and Hubbard (2020, p. 360) argue that *“One of the key considerations for the successful transition of construction activities on-site to a construction process that integrates OSM processes, is the ability of stakeholders to adapt to and embrace this new hybrid construction/manufacturing environment.”* The design, manufacture and construct procurement model reflects Arashpour (2020, p.114) description *“Offsite construction can be considered a unique hybrid of manufacturing and construction, where products are prefabricated in controlled factory environments and then transported and installed on construction sites.”*

Evaluation

The design, manufacture and construct procurement and production sequence (‘DMC model’) was evaluated against Charmaz’s (2006) grounded theory study criteria: credibility, originality, resonance and usefulness at the Modular Matters Conference held on 22 October 2019. The programme featured 14 high profile

speakers who shared their in-depth knowledge with over 200 delegates. The experts interviewed were selected from the speakers and exhibitors.

A corporate banking professional acknowledged that the DMC model met their requirement for an '*Integrated Model*' with single-point responsibility. She recognised that it differed from a traditional arrangement of main and subcontractors. She considered it to be '*very relevant*' and met the credible, resonance and useful criteria. A partner in a solicitors' practice verified the DMC model and considered it similar to ilke Homes's approach – an OSM located outside the region of this study. However, she advised that there should be collaboration between the client's designer and the VOSM in-house designer who tends to rely on standardised design. She recognized that the DMC model reflects the VOSM as a '*one stop shop*' with overall responsibility. She mentioned that this is particularly successful when a client owns a factory. She recommended that all parties should be appointed early. A housing association Director of Development said that the DMC model was credible and identified having prior knowledge of it.

A MPBA (Modular and Portable Building Association) member working for a long-established large modular building manufacturer remarked that he used a similar diagram and found it really useful to explain the modular build process. He had previously mapped the traditional process underneath to demonstrate the compressed timescale. He also emphasised the importance of a design freeze before manufacture and so recommended that there should be no overlap between the design and manufacture sequence bars. He considered the DMC model to be credible, resonant and useful.

A MPBA Director's immediate reaction to the DMC model was '*It's exactly how it works*'. He did, however, suggest some refinements. There may be an earlier design order for planning. Some VOSMs undertake the installation in-house to ensure quality. The groundworks will require design input and should appear as a bar earlier in the sequence in parallel with manufacturing. He concluded that the DMC model is credible, resonates and is very useful. Another MPBA Director recognised the DMC model as a turnkey solution following an original design. He advised that the client's design should only be developed to RIBA Stage 2 concept design as it then needs to be modularised. On this basis, he recommended that the client should appoint an employer's agent and project manager as advisers rather than a designer for the DMC stages. He emphasised the early engagement is paramount. He remarked that the DMC model is '*easy to understand dead simple*', useful and can be superimposed on a RIBA plan of work. He said the DMC model resonates with VOSMs who work directly for the client.

All observations from expert opinions were incorporated in the finalised model presented in this paper. It can therefore be asserted that the DMC model passes the credibility, resonance and usefulness tests. The originality test is more complex. The DMC model is recognised in industry but seems to be original in academia.

Conclusions and future research

There is widespread ambition within the government and business for a greater use of off-site manufacturing by the construction industry. This is of particular importance to increase the supply of new housing to reduce the UK housing deficit.

The literature review, both academic and government policy, identified the absence of appropriate procurement options and applicable forms of contract as barriers to the application of OSM. Organizational management, supply chain and context were classified as under-researched issues.

The increasing importance of the manufacturer and the adjustment required by stakeholders to the hybrid manufacturing/construction environment have been recognized. A definition of volumetric off-site manufacturing incorporating panelized structures and modular methods has been accepted.

The existing procurement methods and forms of contract do not seem to adapt well to use for volumetric off-site manufacturing. A split/two-part contract facilitating payment for planning services and a *JCT modular* contract were requested. The availability and choice of a form of contract to complement VOSM procurement strategy is vital. The need for a standard form for pre-construction contract has been identified. Volumetric off-site manufacturing contract requirements merit further investigation.

A design, manufacture and construct model has been developed for volumetric offsite manufacturing. The DMC model passed credibility, resonance and usefulness tests by the expert opinions. The DMC model is intended to be disseminated via the Volumetric Homes Group of the MPBA. A presentation at the Explore Offsite Housing Conference is also planned. However, the DMC model would benefit from wider geographic and other construction sector scrutiny.

This study could advance the evolution of procurement by the adoption of the innovative design, manufacture and construct model. Furthermore, the DMC model may inform the development of OSM policies consequently influencing clients in their choice of procurement strategy. However resistance to change, particularly by clients, should not be underestimated.

References

- Agapiou, A (2020), "Optimising the use of off-site manufactured components in the UK house-building sector: Understanding the legal and contractual issues", in Goulding, J. and Rahimian, F. (eds) *Offsite Production and Manufacturing for Innovative Construction*, Routledge, Abingdon.
- Akintan, O. and Morledge (2013), "Improving the Collaboration between Main Contractors and Subcontractors within Traditional Construction Procurement" *Journal of Construction Engineering*, Vol 2013, Article ID 281236, 11 pages
- Arashpour, M., Wakefield R., Lee, E., Chan R., and Hosseini, M. (2016), "Analysis of interacting uncertainties in on-site and off-site activities: Implications for hybrid construction." *International Journal of Project Management*, Vol 34, pp. 1393-1402.
- Arashpour, M. (2020), "Design for manufacture and assembly in offsite construction and relationship with concurrent engineering", in Goulding, J. and Rahimian, F. (eds) *Offsite Production and Manufacturing for Innovative Construction*, Routledge, Abingdon.
- Banks C., Kotecha R., Curtis, J., Dee C., Pitt, N. and Papworth, R. (2018), "Enhancing high-rise residential construction through design for manufacture and assembly – a UK case study" *Proceedings of the Institution of Civil Engineers – Management, Procurement and Law*, Vol 171 Issue 4 pp. 164 - 175
- Brawn, V. and Clarke, V. (2013), *Successful Qualitative Research*, Sage, London.
- Bryman, A. (2016), *Social Research Methods*. 5th ed., Oxford University Press, Oxford.
- Charlson J. (2019), "Briefing: Interpreting contractors' mandated standard of design" *Proceedings of the Institution of Civil Engineers – Management, Procurement and Law*, Vol 172 Issue 4 pp. 142-145
- Charmaz, K. (2006), *Constructing Grounded Theory: A Practical Guide through Qualitative Analysis*, Sage, London.
- Chartered Institute of Housing (2019), *Submission to the Housing, Communities and Local Government Committee inquiry into modern methods of construction*, available at:
<http://www.cih.org/resources/policy/Consultation%20responses/CIH%20response%20to%20HoC%20MMC%20inquiry%20Mar19.pdf> (accessed 11 April 2019).
- Chun Tie, Y., Birks, M. and Francis, K. (2019) Grounded theory research: A design framework for novice researchers. *SAGE Open Medicine*. Available at:
<https://doaj.org/article/10a453b7431c4c03bd77634d42f84340> (accessed 28 October 2019)

Commons Select Committee (2018), *New Inquiry: Modern Methods of Construction* available at: <https://www.parliament.uk/business/committees/committees-a-z/commons-select/housing-communities-and-local-government-committee/news/modern-construction-inquiry-launched-17-19/> (accessed 12 April 2019).

Construction Leadership Council (2017) *Innovation in Buildings Workstreams*. Position Paper November 2017, available at: <http://www.constructionleadershipcouncil.co.uk/wp-content/uploads/2017/11/Demand-Surity-Report-September-2017-VF-WEB-final.pdf> (accessed 6 September 2018).

Creswell, J. (2014), *Research Design: Qualitative, Quantitative, and Mixed Methods approaches*, 4th ed., Sage, London.

Crotty, M. (1998), *The Foundations of Social Research: Meaning and Perspective in the Research Process*, Sage, London.

Dowsett, R., Green, M., Sexton, M. and Harty, C. (2019), "Projecting at the project level: MMC supply chain integration roadmap for small housebuilders". *Construction Innovation*, Vol 19 No.2, pp. 193–211.

El Asmar M., Hanna, A. and Loh, W. (2013) "Quantifying Performance for the Integrated Project Delivery System as Compared to Established Delivery Systems" *Journal of Construction Engineering and Management*, Vol 139 No.11, 04013012

Elnaas, H., Gidado, K. and Ashton, P. (2014), "Factors and Drivers Effecting the Decision of Using Off-Site Manufacturing (OSM) Systems in House Building Industry", *Journal of Engineering, Project and Production Management*, Vol. 4 No. 1, pp. 51-58.

Farmer, M. (2016) *The Farmer Review of the UK Construction Labour Model – Modernise or Die*, Construction Leadership Council, available at: <http://www.constructionleadershipcouncil.co.uk/wp-content/uploads/2016/10/Farmer-Review.pdf> (accessed 28 October 2019).

Fawcett, B. and Pockett P. (2015), *Turning Ideas into Research: Theory Design & Practice*, Sage, London.

Fink, A. (2014), *Conducting Research Literature Reviews: From the Internet to Paper*, 4th ed., Sage, London.

Finnie D. (2018), "Enhancing off-site manufacturing through early contractor involvement (ECI) in New Zealand" *Proceedings of the Institution of Civil Engineers – Management, Procurement and Law*, Vol 171 Issue 4 pp. 176-185

Goulding, J. and Rahimian, F. (2020), "Offsite manufacturing: Envisioning the future agenda", in Goulding, J. and Rahimian, F. (eds) *Offsite Production and Manufacturing for Innovative Construction*, Routledge, Abingdon.

Hale, D., Shrestha P., Gibson, G. and Migliaccio, G. (2009) "Empirical Comparison of Design/Build and Design/Bid/Build Project Delivery Methods" *Journal of Construction Engineering and Management*, Vol 135 No.7 pp.579-587

Hammad, A., Sutrisna, M. and Zaman, A. (2020), "Towards optimising OSM implementation in construction projects", in Goulding, J. and Rahimian, F. (eds) *Offsite Production and Manufacturing for Innovative Construction*, Routledge, Abingdon.

Mesa, H., Molenaar, K. and Alarcon, L. (2016), "Exploring performance of integrated project delivery process on complex building projects." *International Journal of Project Management*, Vol 34 No.7, pp. 1089-1101.

HM Government (2013) *Construction 2025*, available at:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/210099/bis-13-955-construction-2025-industrial-strategy.pdf,

HM Treasury (2017) *Autumn Budget 2017*, available at:
<https://www.gov.uk/government/publications/autumn-budget-2017-documents/autumn-budget-2017> (accessed 28 October 2019)

House of Lords (2018) *Off-site manufacture for construction: Building for change*. HL Paper 169, available at:
<https://publications.parliament.uk/pa/ld201719/ldselect/ldsctech/169/169.pdf>
(accessed 6 September 2018).

Hubbard B. and Hubbard S. (2020), "Stakeholder transformation in OSM infrastructure construction", in Goulding, J. and Rahimian, F. (eds) *Offsite Production and Manufacturing for Innovative Construction*, Routledge, Abingdon.

Hunter, K. and Kelly, J. (2008), "Grounded theory", in Knight, A. and Ruddock, L. (eds.) *Advanced Research Methods in the Built Environment*, Blackwell Publishing, Oxford.

King, A. (2008), "Using software to analyse qualitative data", in Knight, A. and Ruddock, L. (eds.) *Advanced Research Methods in the Built Environment*, Blackwell Publishing, Oxford.

King, N. and Horrocks, C. (2010), *Interviews in qualitative research*, Sage, London.

Lau, C, Mesthrige, J., Lam, P. and Javed A. (2019), "The challenges of adopting new engineering contract: a Hong Kong." *Engineering, Construction and Architectural Management*, Vol 26 No.10, pp. 2389-2409.

- Liu, G., Nzige, J. and Li, K. (2019), "Trending topics and themes in offsite construction (OSC) research", *Construction Innovation*, Vol.19 No.3, pp.343–366.
- Lupton, S., Stellakis, M. and Clamp, H. (2019), *Which contract? : choosing the appropriate building contract*, 6th ed., RIBA Publishing, London.
- London Assembly (2017) *Designed, sealed, delivered – The contribution of offsite manufactured homes to solving London's housing crisis*, available at: https://www.london.gov.uk/sites/default/files/london_assembly_osm_report_0817.pdf (accessed 6 September 2018).
- Mills, J., Briks, M., and Hoare, K. (2014). "Grounded theory". in Mills, J. and Briks, M.(eds) *Qualitative Methodology: a practical guide*, Sage, London.
- Mohsini, R., Sirpal, R. and Davidson, C. (1995) "Procurement: A comparative analysis of construction management and traditional building processes" *Building Research and Innovation* Vol. 23 No.5 pp.285-290
- Mosley, J. and Bubshait, A. (2017), "Project procurement systems for mechanical, electrical and piping projects in Saudi Arabia." *Engineering, Construction and Architectural Management*, Vol 24 No.6, pp. 1004-1017.
- Nadim, W. and Goulding, J. (2010), "Offsite production in the UK: the way forward? A UK construction industry perspective", *Construction Innovation*, Vol.10 No.2, pp.181-202.
- NBS (2018) *National Construction Contracts and Law Report 2018*. Newcastle upon Tyne: NBS, available at: <https://www.thenbs.com/knowledge/national-construction-contracts-and-law-report-2018> (accessed 21 October 2019).
- Rahman, M. (2014), "Barriers of implementing modern methods of construction", *Journal of Management in Engineering*, Vol.30 No.1 pp.69-77
- Rahmani, F., Maqsood, T.and Khalfan, M. (2017), "An overview of construction procurement methods in Australia." *Engineering, Construction and Architectural Management*, Vol 24 No.4, pp. 593–609.
- Schwandt, T. (2001), *Dictionary of Qualitative Inquiry*. 2nd ed., Sage, London
- Sutrisna, M. and Goulding, J. (2019), "Managing information flow and design processes to reduce design risks in offsite construction projects", *Engineering, Construction and Architectural Management*, Vol.26 No.2, pp. 267-284.
- Silverman, D. (2011), *Interpreting Qualitative Data*. 4th ed., Sage, London.
- Small, E. (2020), "Core OSM implementation strategies", in Goulding, J. and Rahimian, F. (eds) *Offsite Production and Manufacturing for Innovative Construction*, Routledge, Abingdon.

Taylor, M. (2010), "A definition and valuation of the UK offsite construction sector",
Construction Management and Economics, Vol.28 No.8, pp.885-896